

^{AV}U. S. Shale Gas Resources: Classic and Emerging Plays, the Resource Pyramid and a Perspective on Future E&P*

By

John B. Curtis¹, David G. Hill², and Paul G. Lillis³

Search and Discovery Article #110066 (2008)

Posted September 13, 2008

*Prepared for presentation at AAPG Annual Convention, San Antonio, Texas, April 20-23, 2008

¹Geology & Geological Engineering, Colorado School of Mines, Golden, CO (jbcurtis@mines.edu)

²EnCana Oil and Gas (USA), Inc., Denver, CO

³U.S. Geological Survey

Abstract

Projections by the United States government indicate that annual U.S. gas demand could increase from the current 22 Tcf (trillion cubic feet) to 26 Tcf by the year 2030. This would occur during a period of declining Canadian gas imports and increasing U.S. reliance on LNG imports, a commodity only available in a highly competitive market. The robustness of the North American gas resource base, particularly shale gas, coalbed methane, and tight sands gas needs to be quantified.

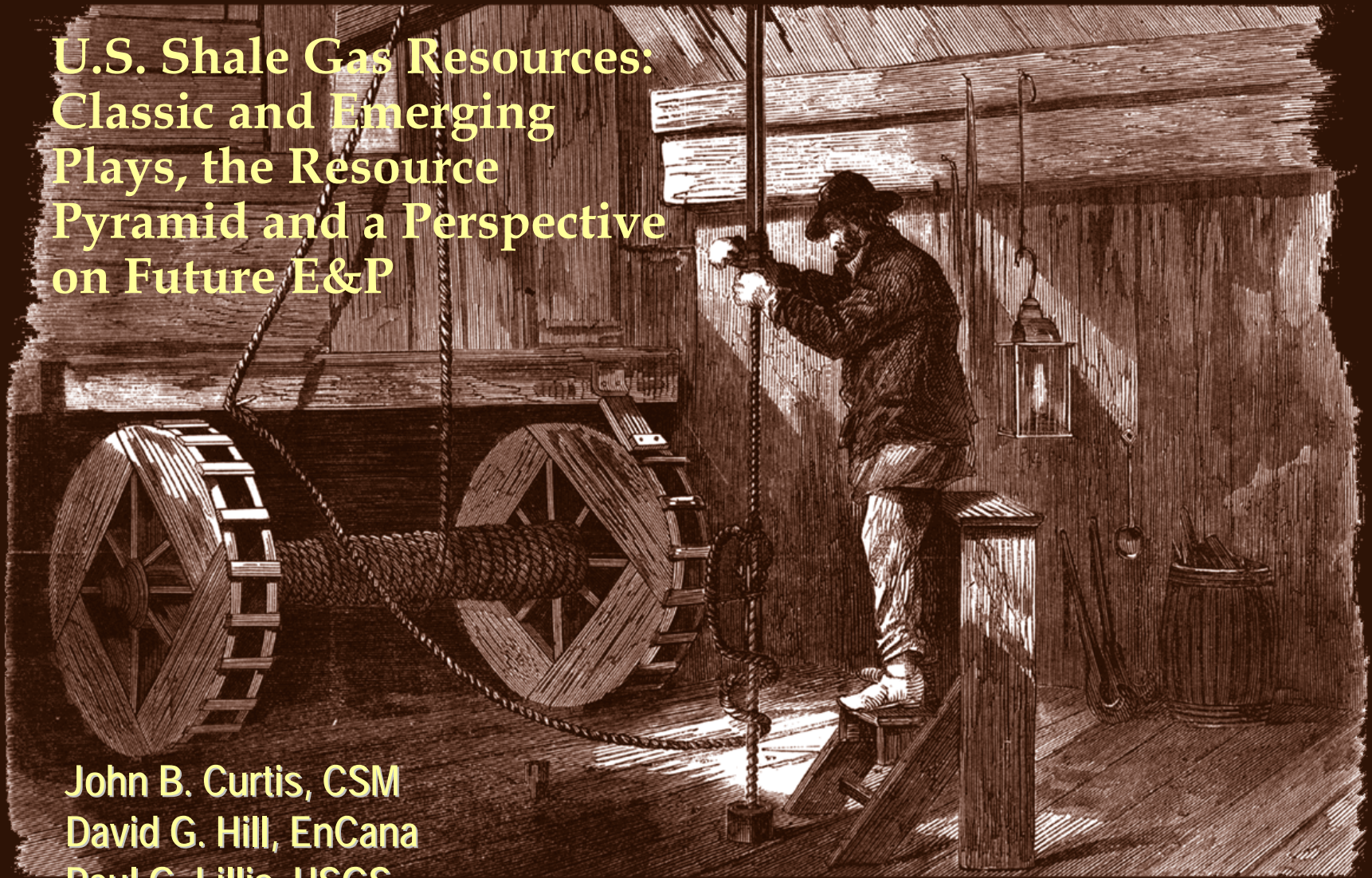
Shale gas production, which dates from 1821 in the United States, is now rapidly increasing, accounting for approximately 5% of annual production. The U. S. Energy Information Administration estimates that shale gas production will overtake coalbed methane production by 2025, and will grow from the current 1 Tcf to 2.3 Tcf annually by 2030.

Shale gas is also an increasingly large component of future, technically recoverable resources. Both of these trends are due to improvements in exploration, completion, and production technologies, aided by wellhead price increases.

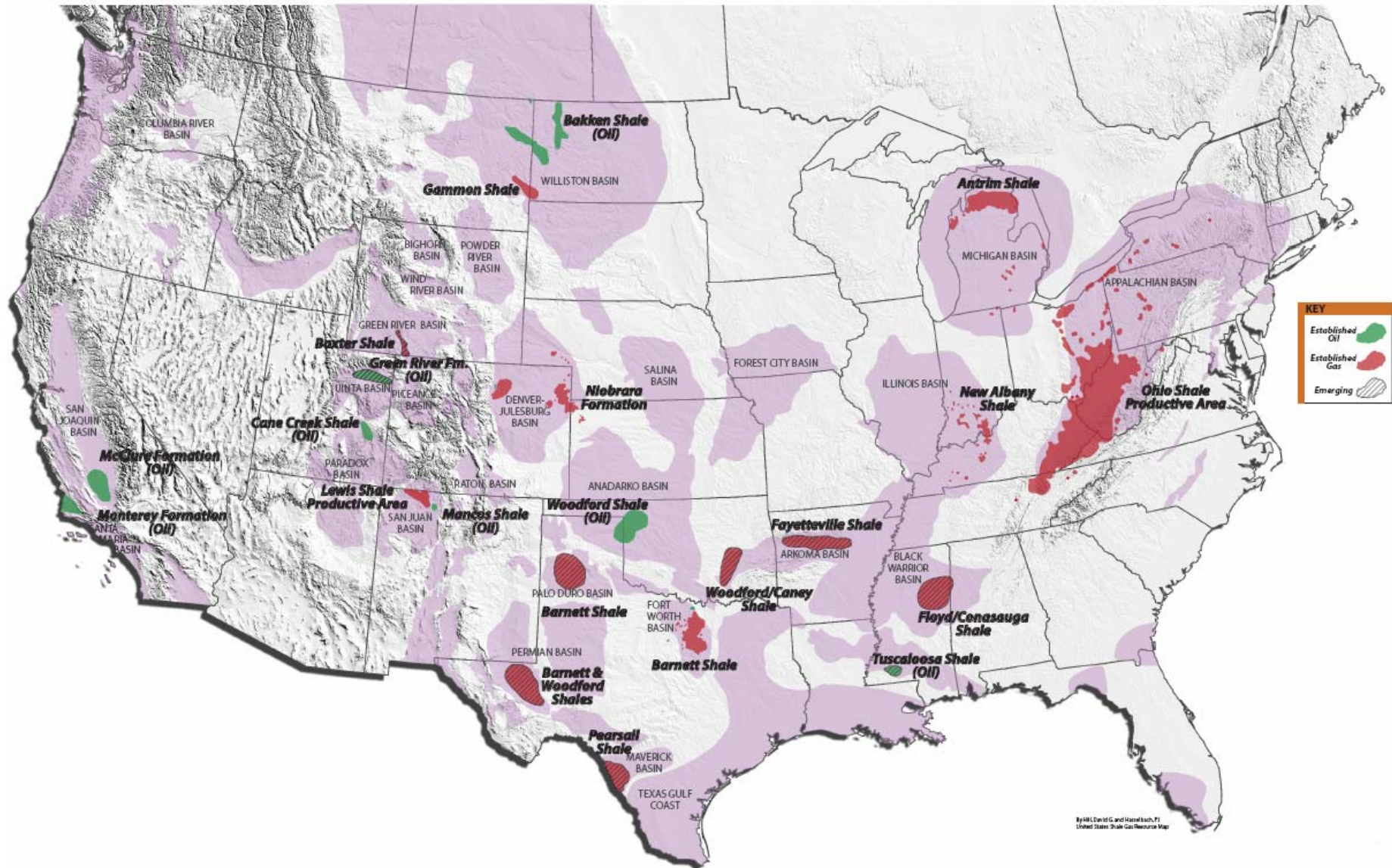
The latest Potential Gas Committee biennial assessment, (September, 2007), shows an overall increase of 18% (200 Tcf) for total U.S. gas resources. The bulk of this increase is for shale gas resources assessed in the Appalachian, Anadarko, Arkoma, Ft. Worth, and Permian basins. This paper analyses shale gas future potential in light of past production, current proved reserves, and the geological and economic realities of current and emerging Lower-48 U. S. plays.

U.S. Shale Gas Resources: Classic and Emerging Plays, the Resource Pyramid and a Perspective on Future E&P

John B. Curtis, CSM
David G. Hill, EnCana
Paul G. Lillis, USGS

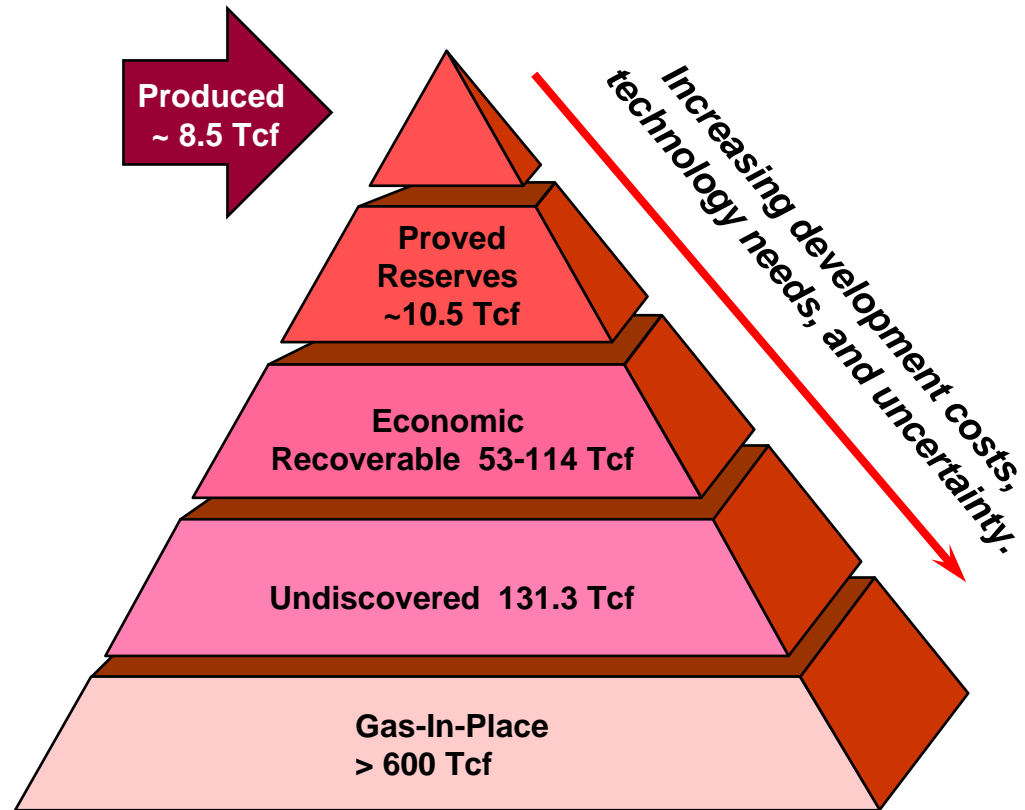


Major U.S. Basins and Shale Plays



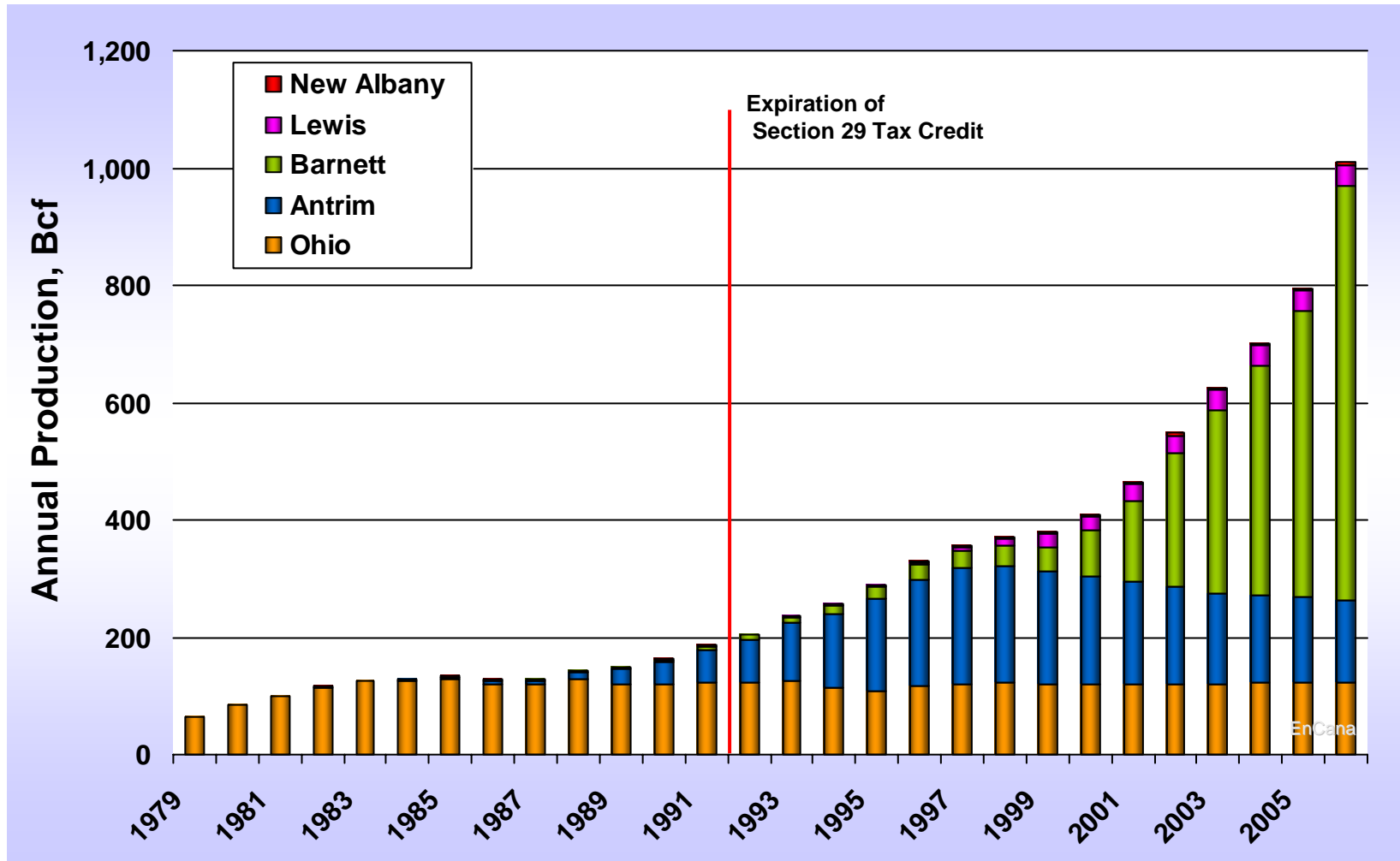
Lower-48 Shale Gas Resource Base

**264 Tcf Total Producible
Shale Gas Resource Base**

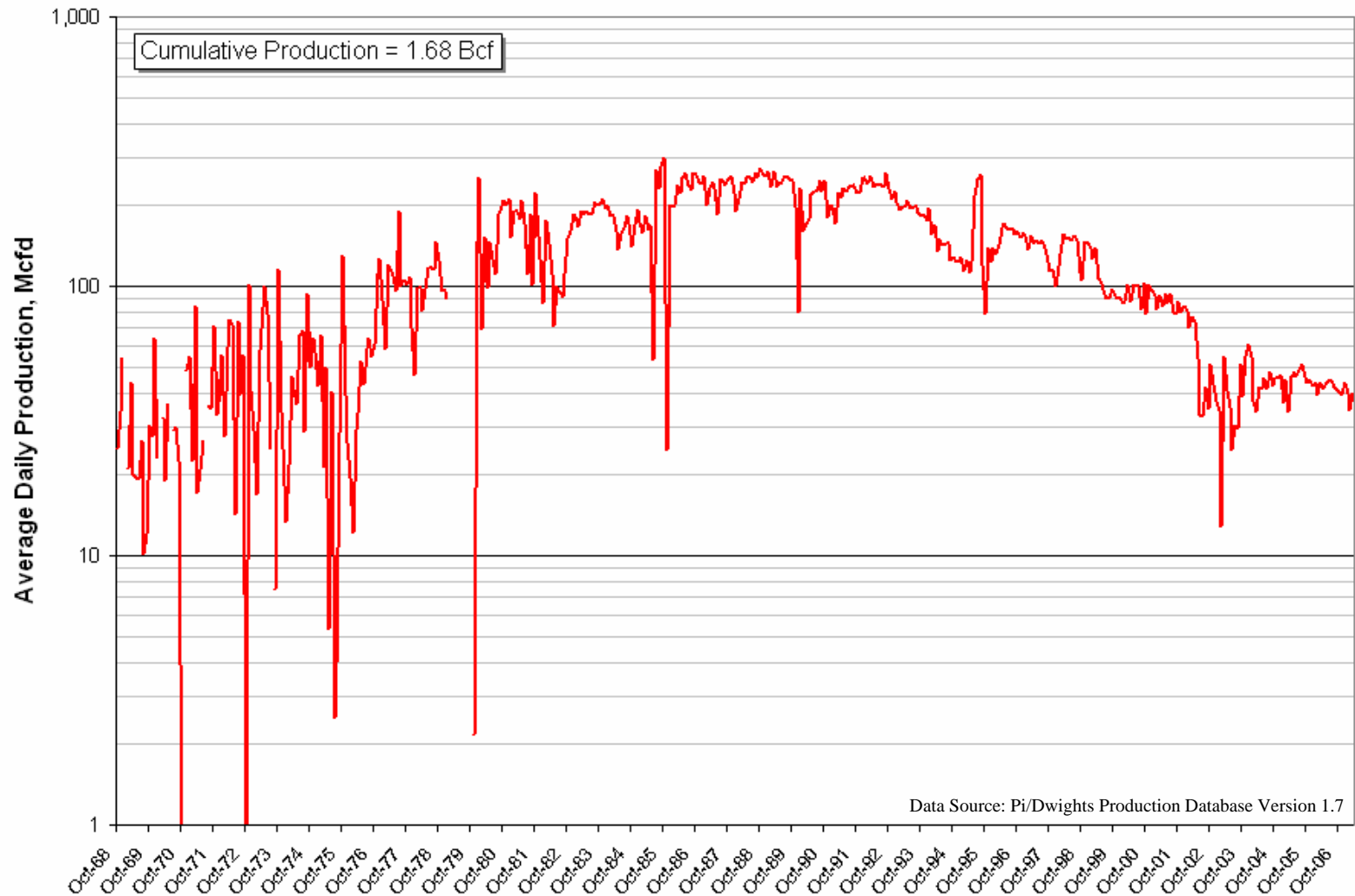


Modified and Updated from Hill and Nelson, 2000

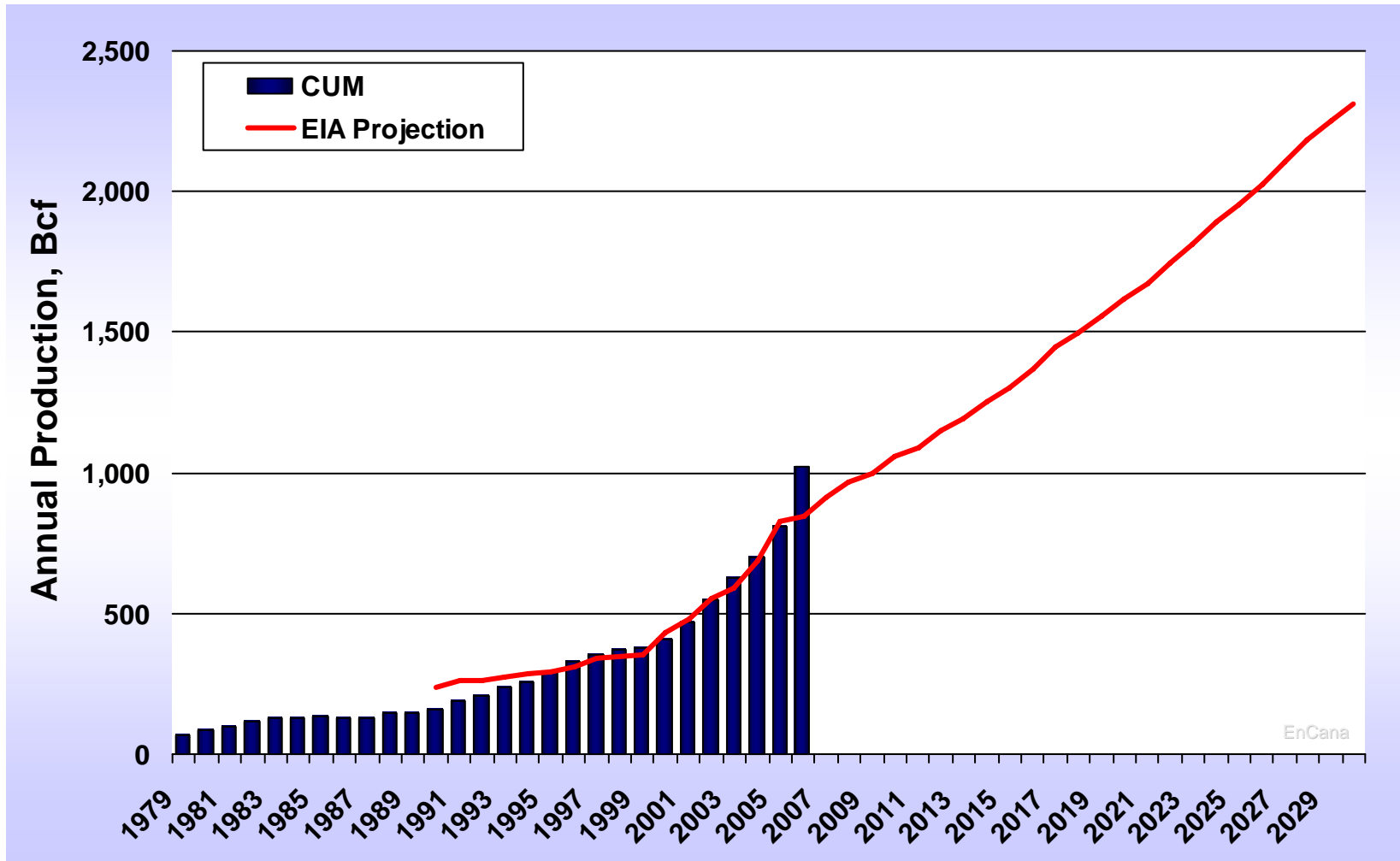
U.S. Shale Gas Annual Production from Five Principal (Classic) Plays



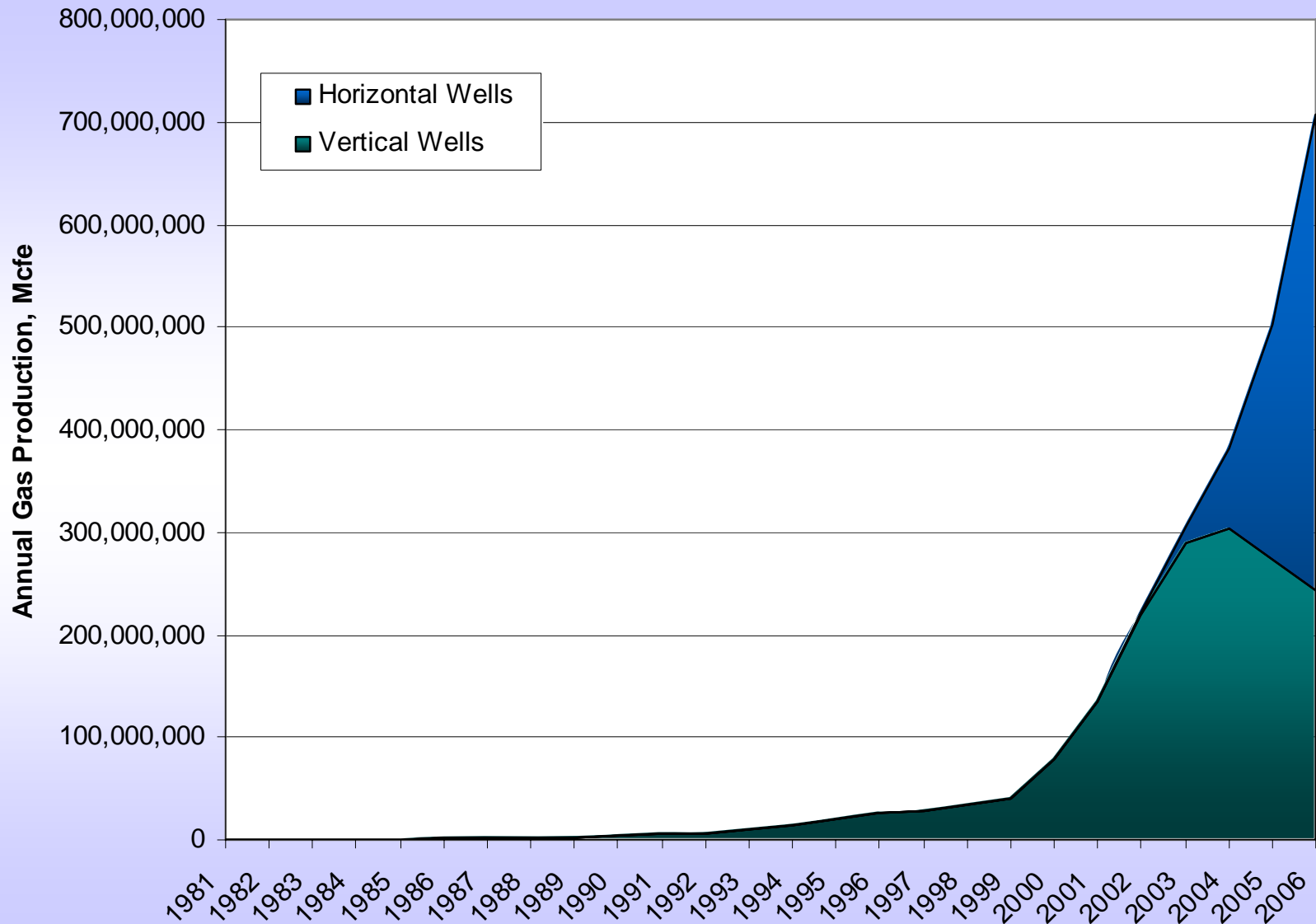
Ausable 9-34 Antrim Shale Natural Gas Production



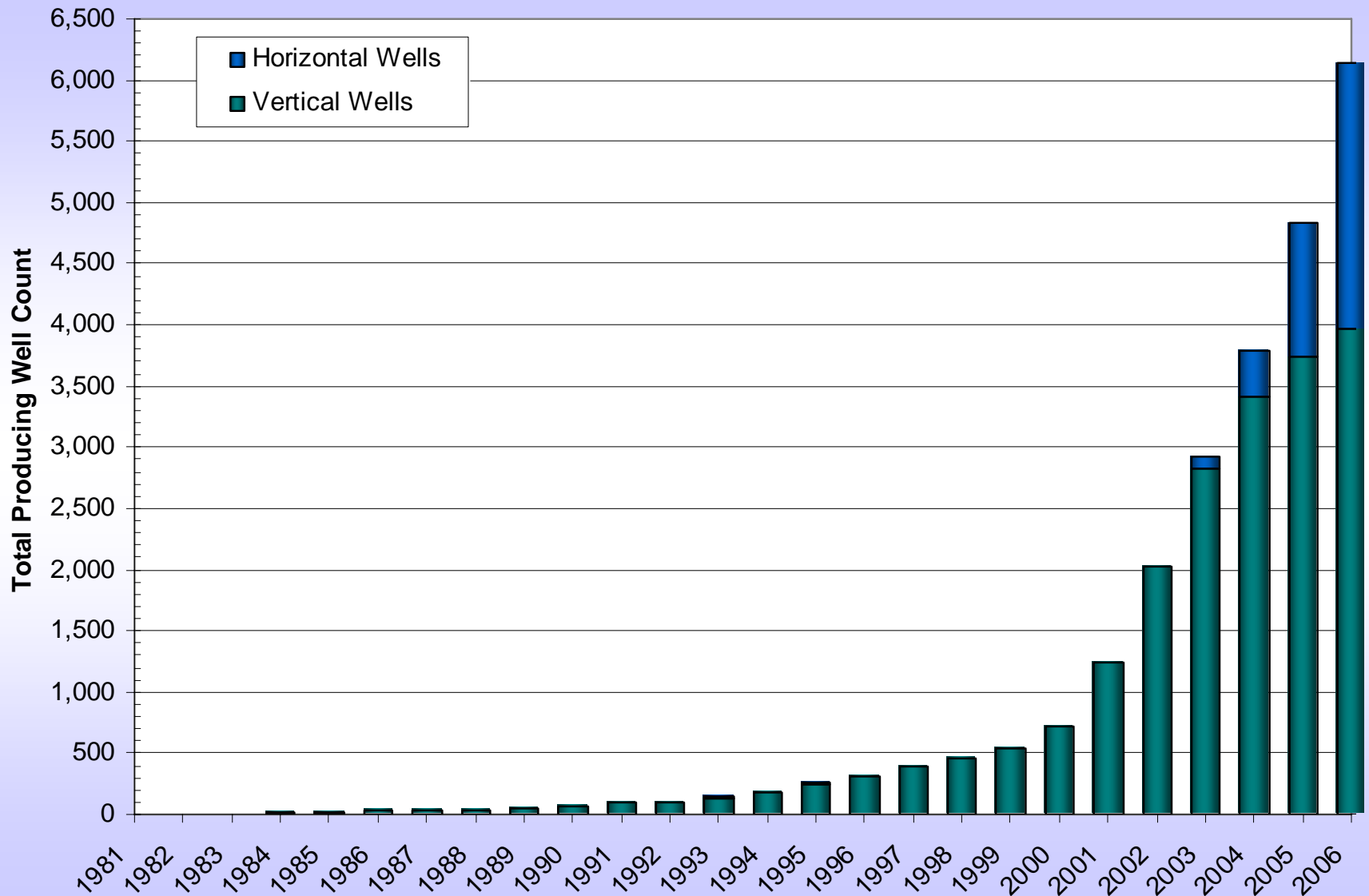
Shale Gas Annual Production and Energy Information Administration (EIA) Forecast



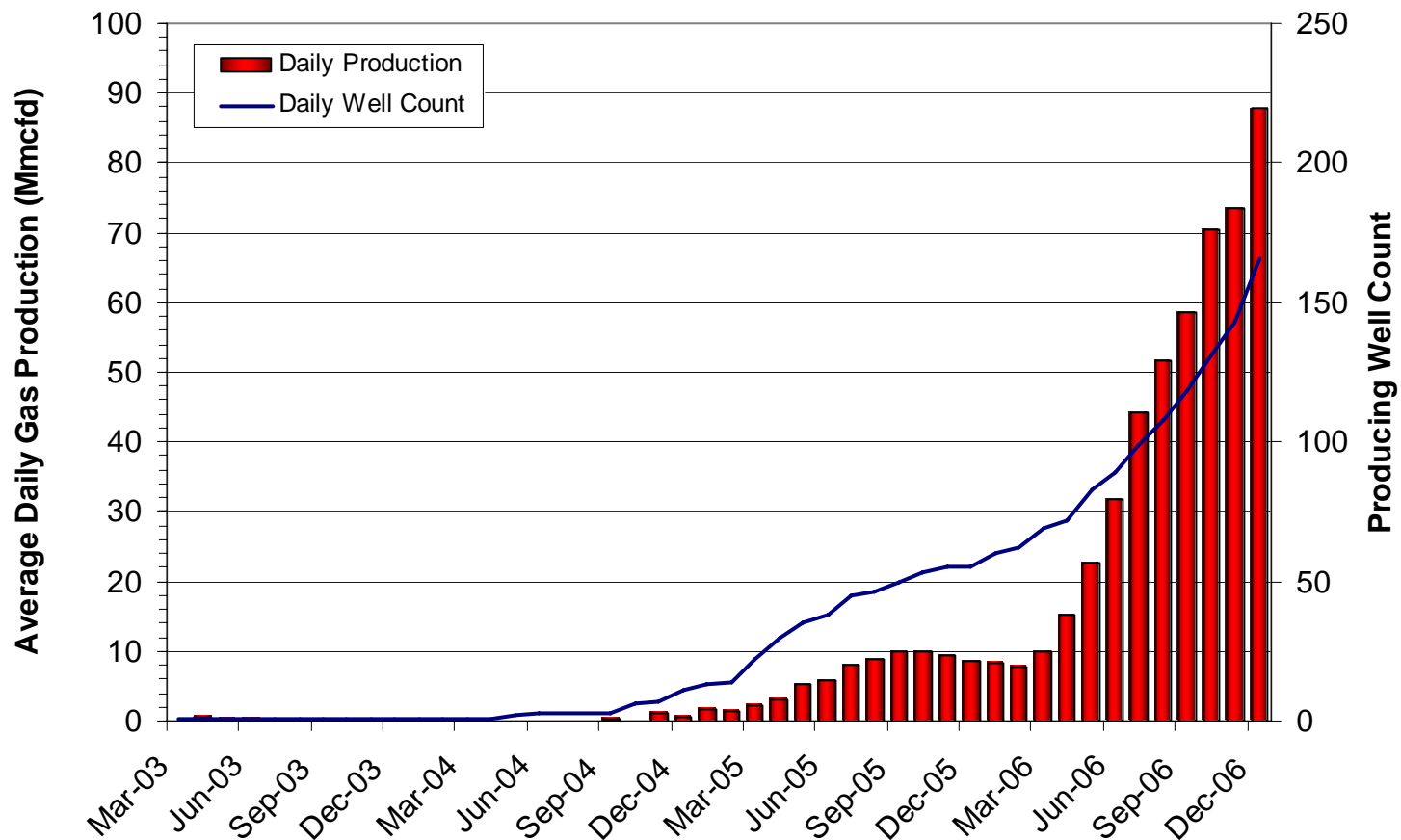
Barnett Shale Annual Natural Gas Production, Fort Worth Basin (Data Source: IHS)



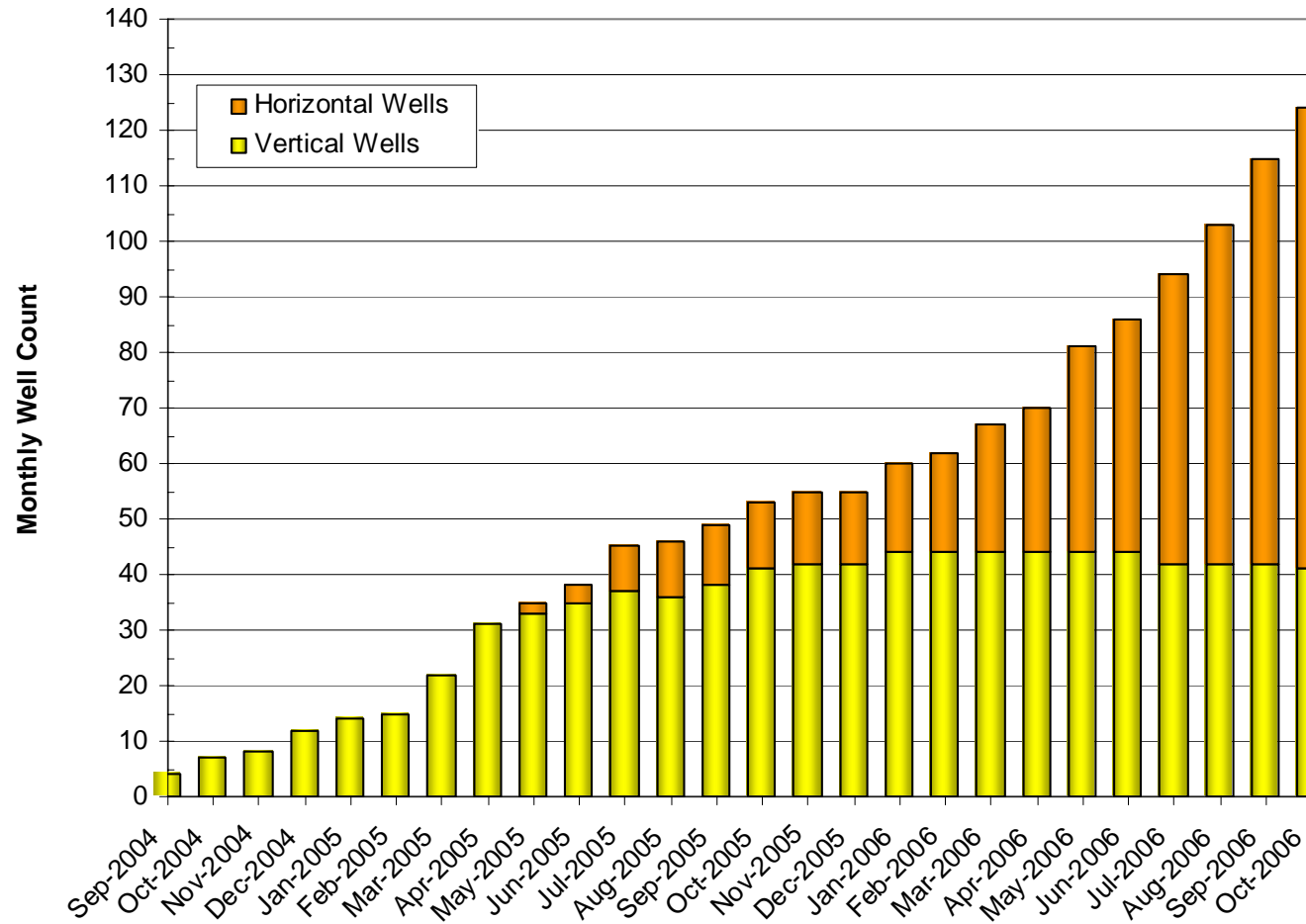
Barnett Shale Annual Producing Well Count, Fort Worth Basin (Data Source: IHS)



Fayetteville Shale Average Daily Production and Producing Well Count (Data Source: IHS)

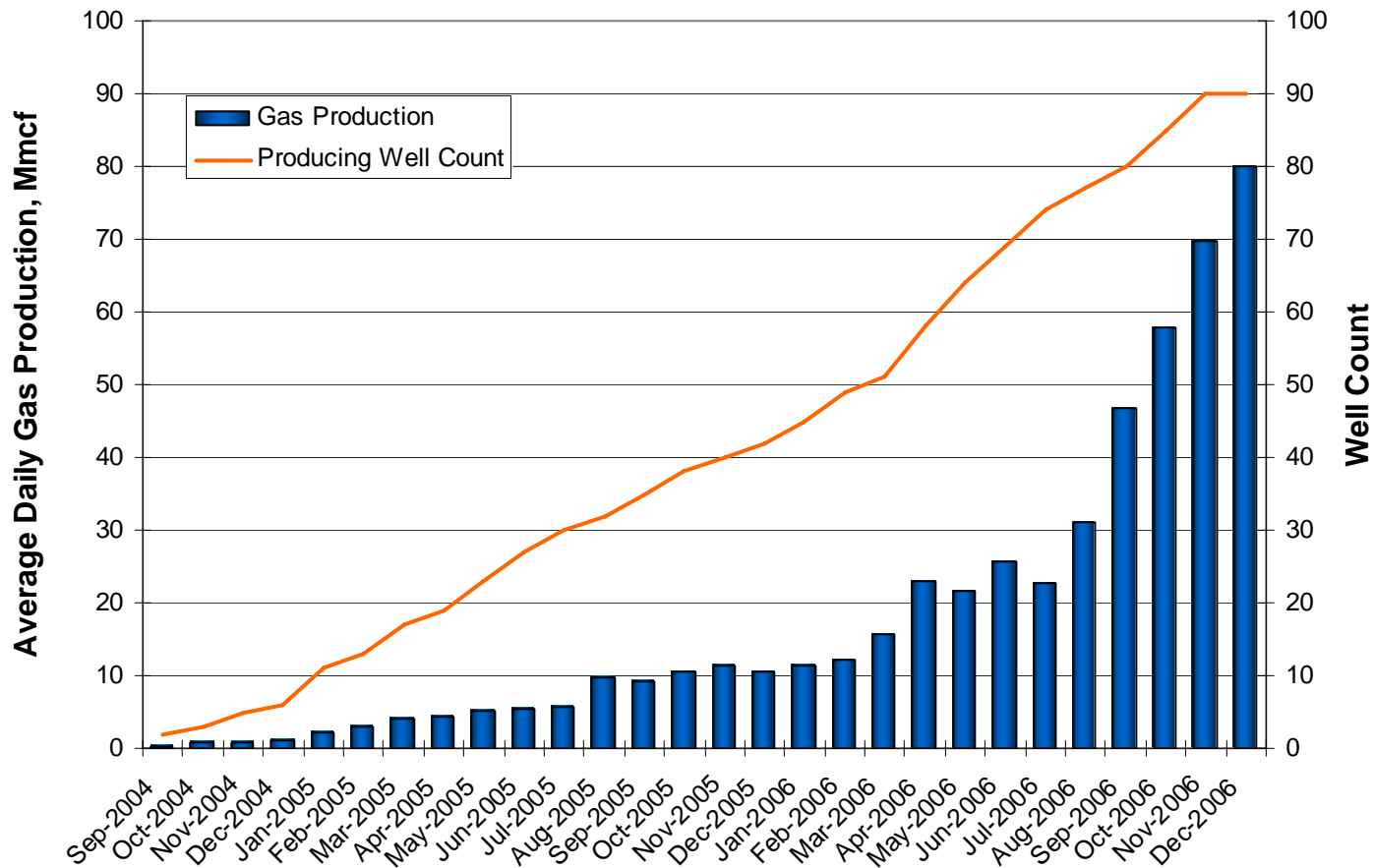


Fayetteville Shale Monthly Producing Well Count by Type (Data Source: IHS)

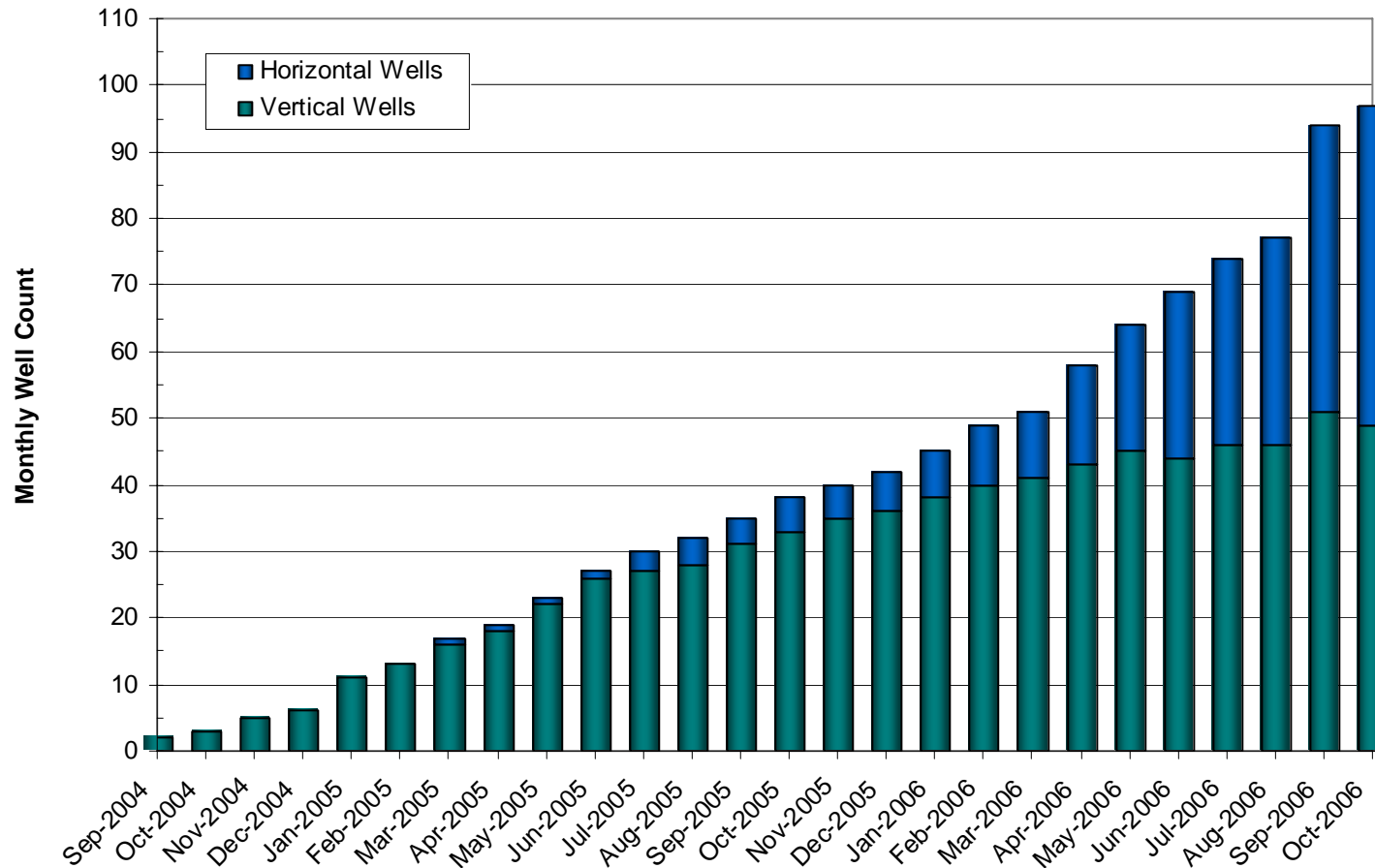


Woodford Shale Average Daily Production and Producing Well Count, Arkoma Basin

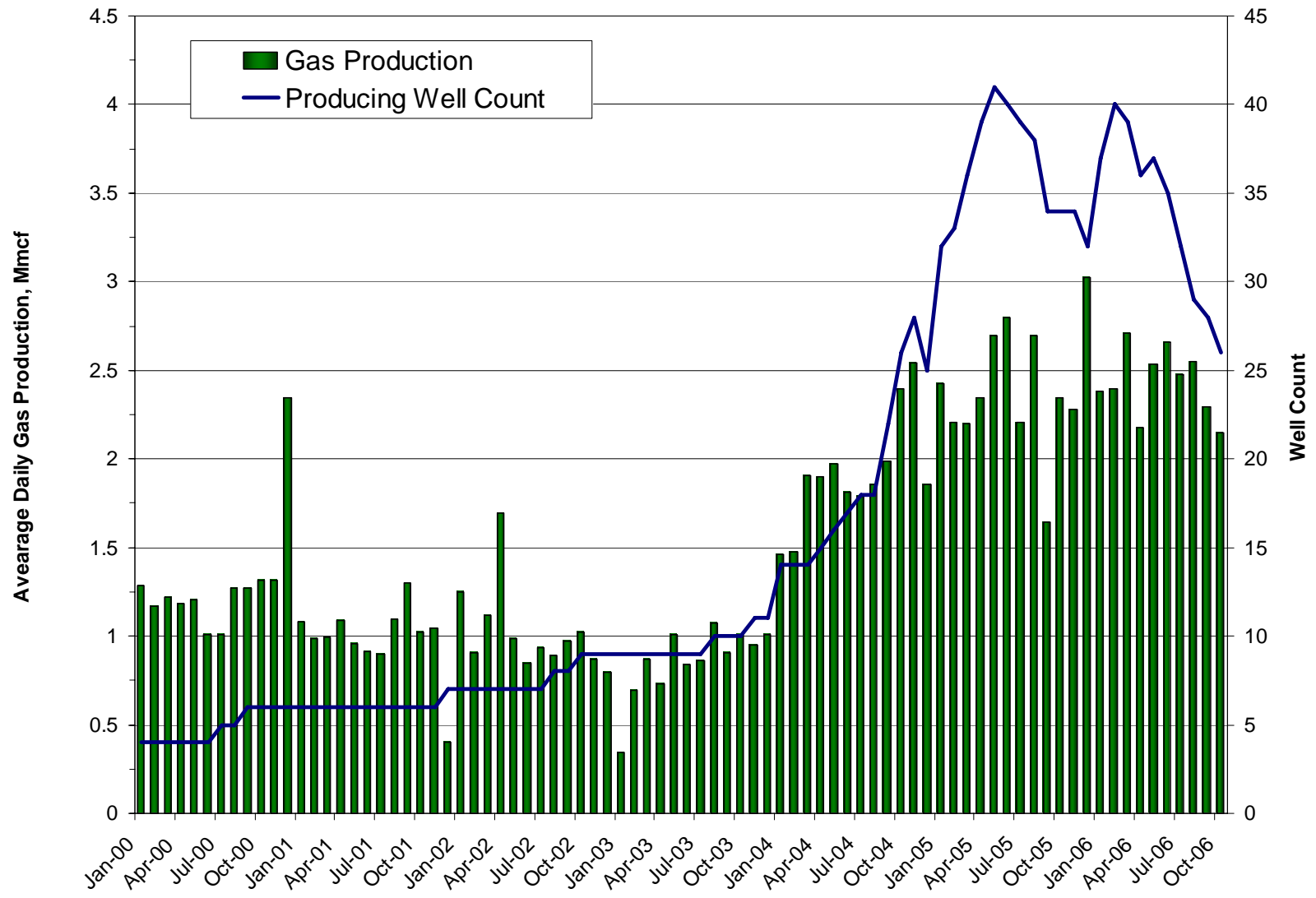
(Data Source: IHS)



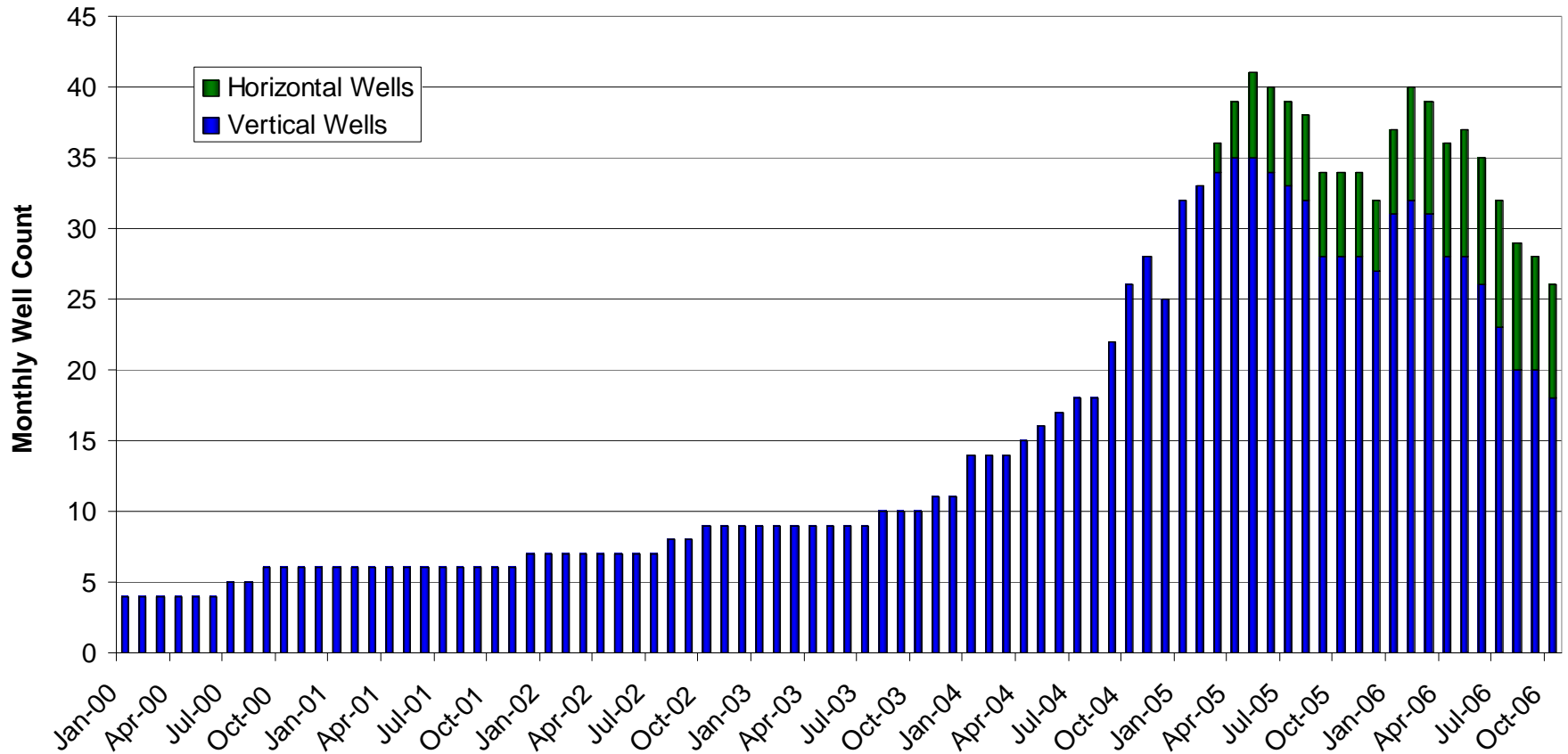
Woodford Shale Monthly Producing Well Count by Type, Arkoma Basin (Data Source: IHS)



Caney Shale Average Daily Production and Producing Well Count, Arkoma Basin (Data Sources: IHS; Cardott, 2007)

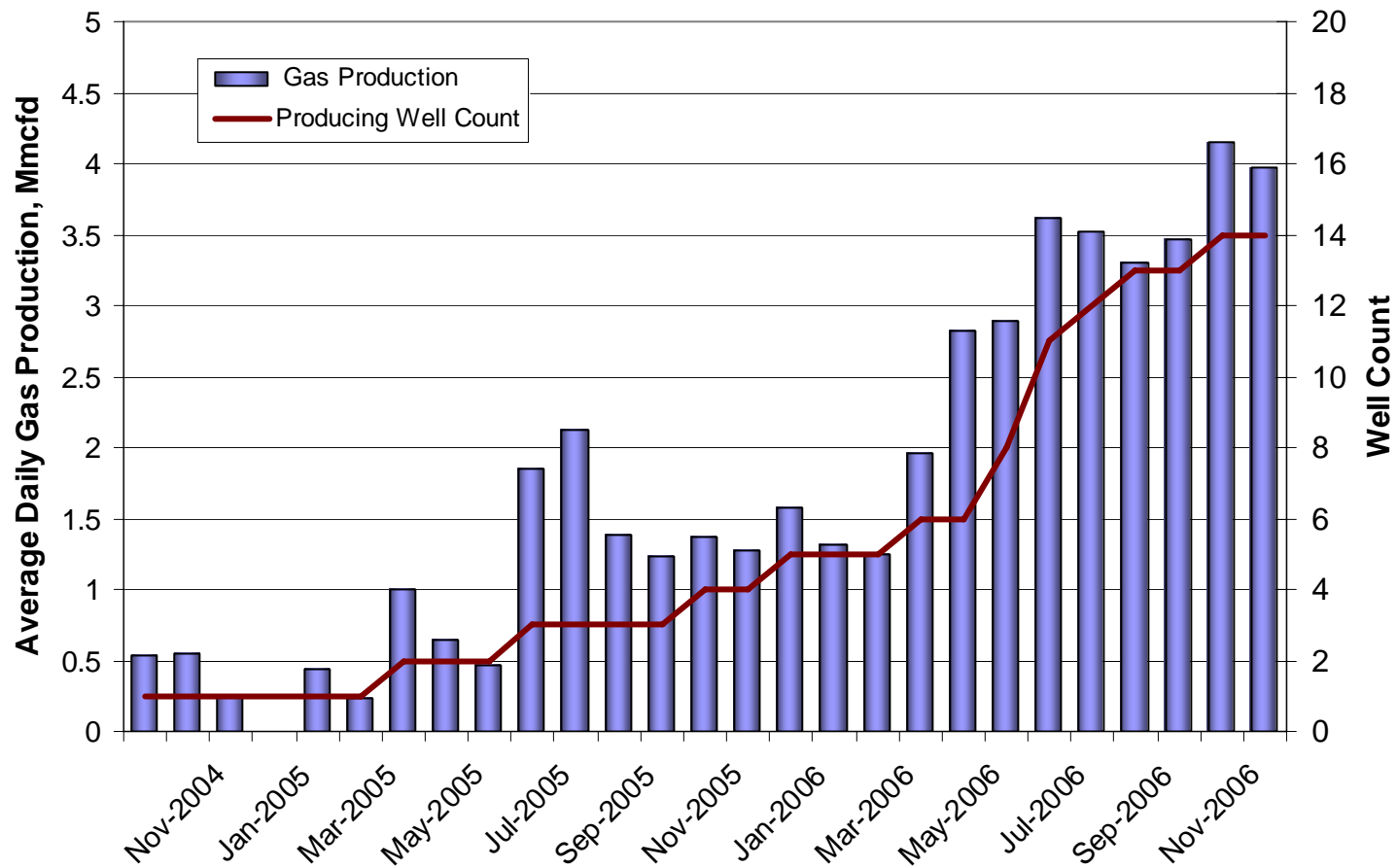


Caney Shale Monthly Producing Well Count by Type, Arkoma Basin (Data Source: IHS)

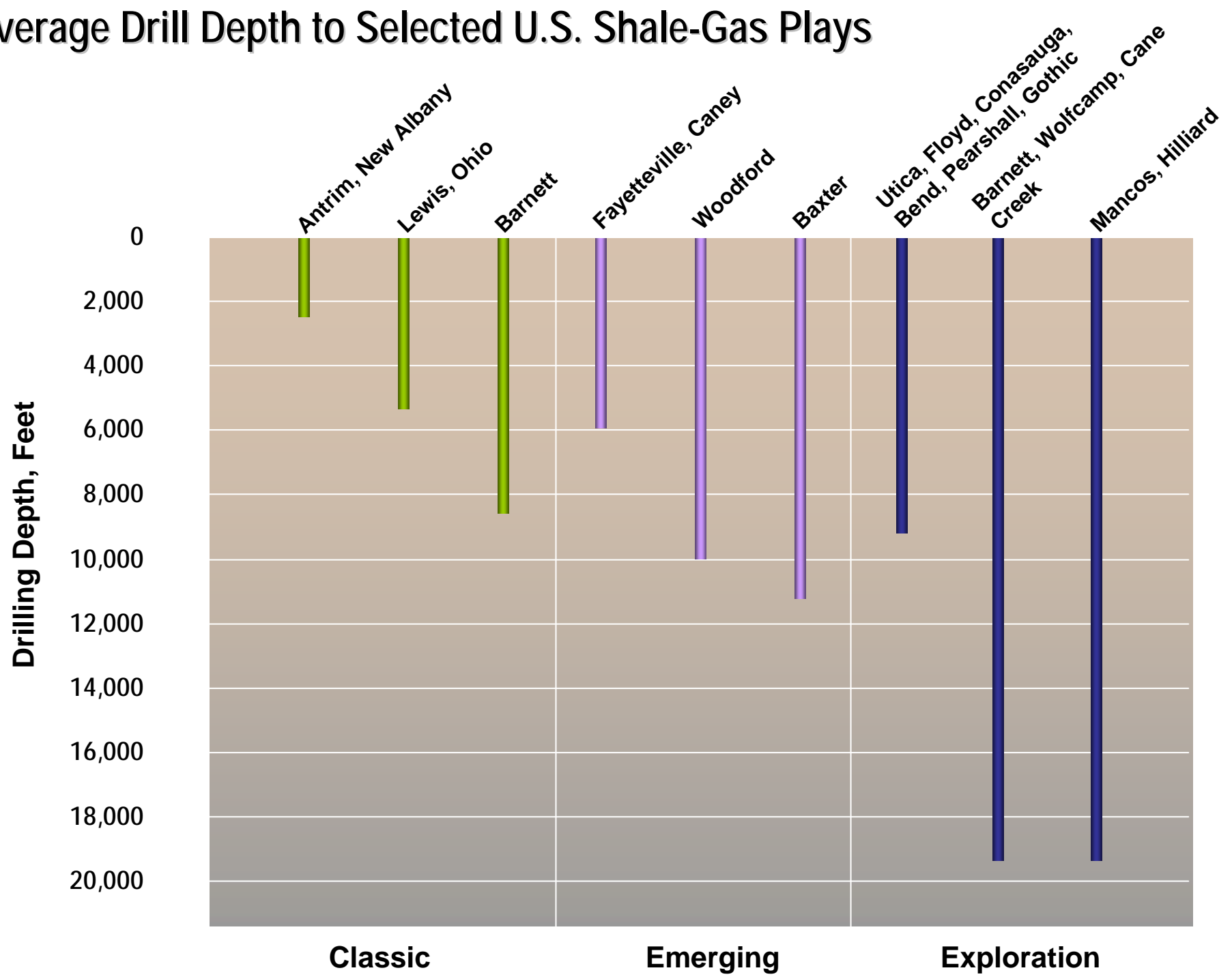


Baxter Shale Average Daily Production and Producing Well Count, Vermillion Basin

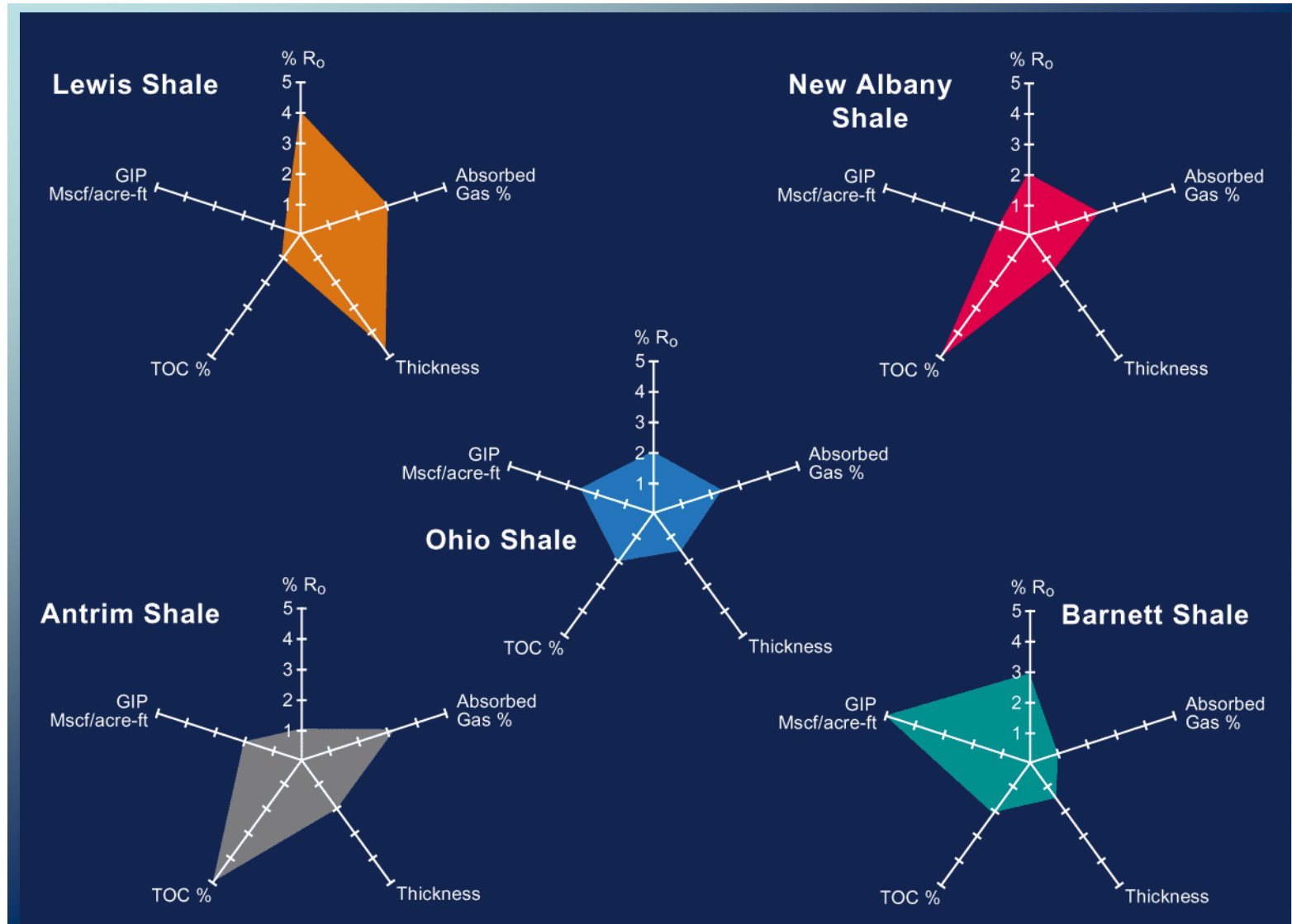
(Data Source: IHS)



Average Drill Depth to Selected U.S. Shale-Gas Plays

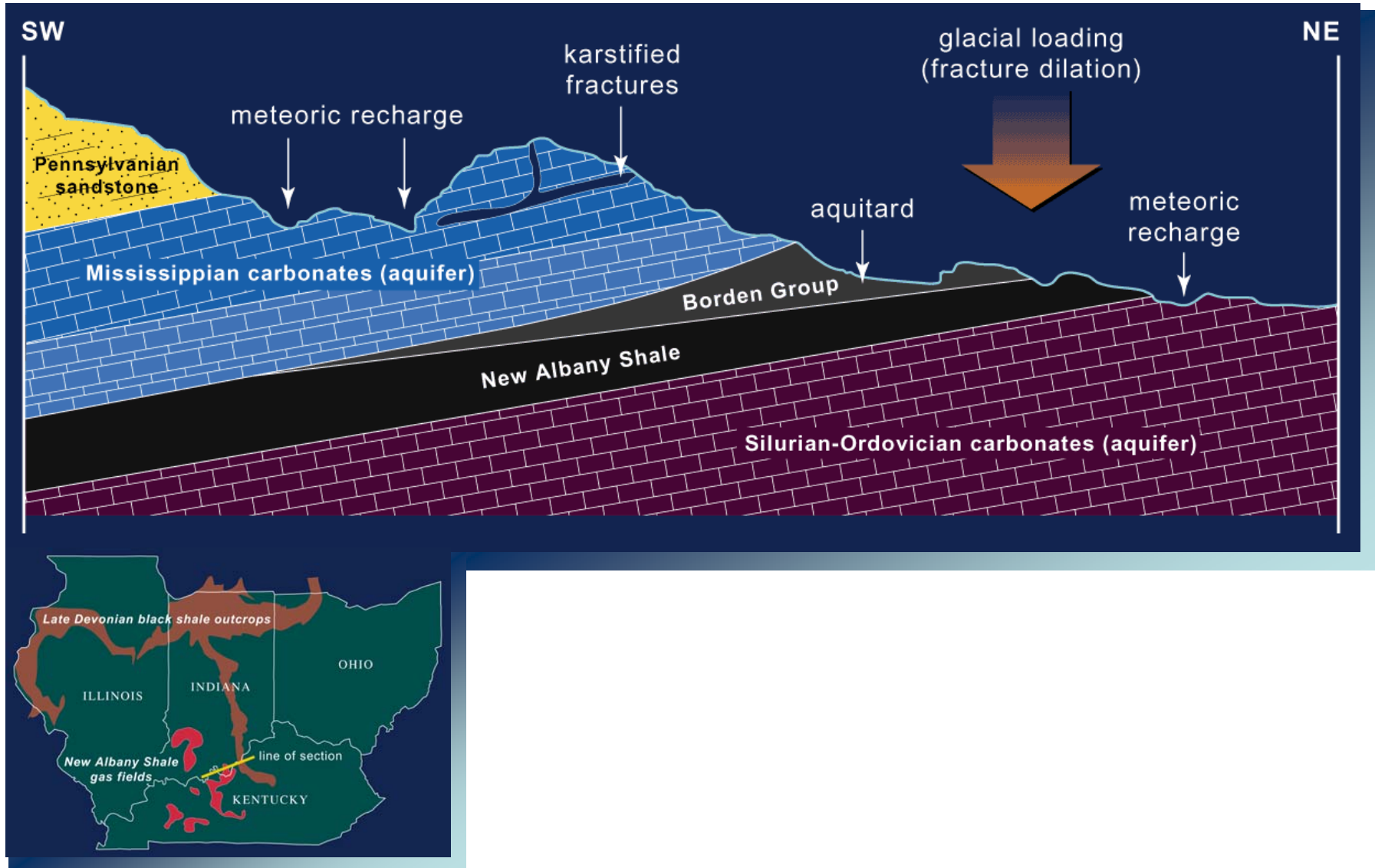


Geochemical Properties of Gas Shales (Modified from Hill and Nelson, 2000)

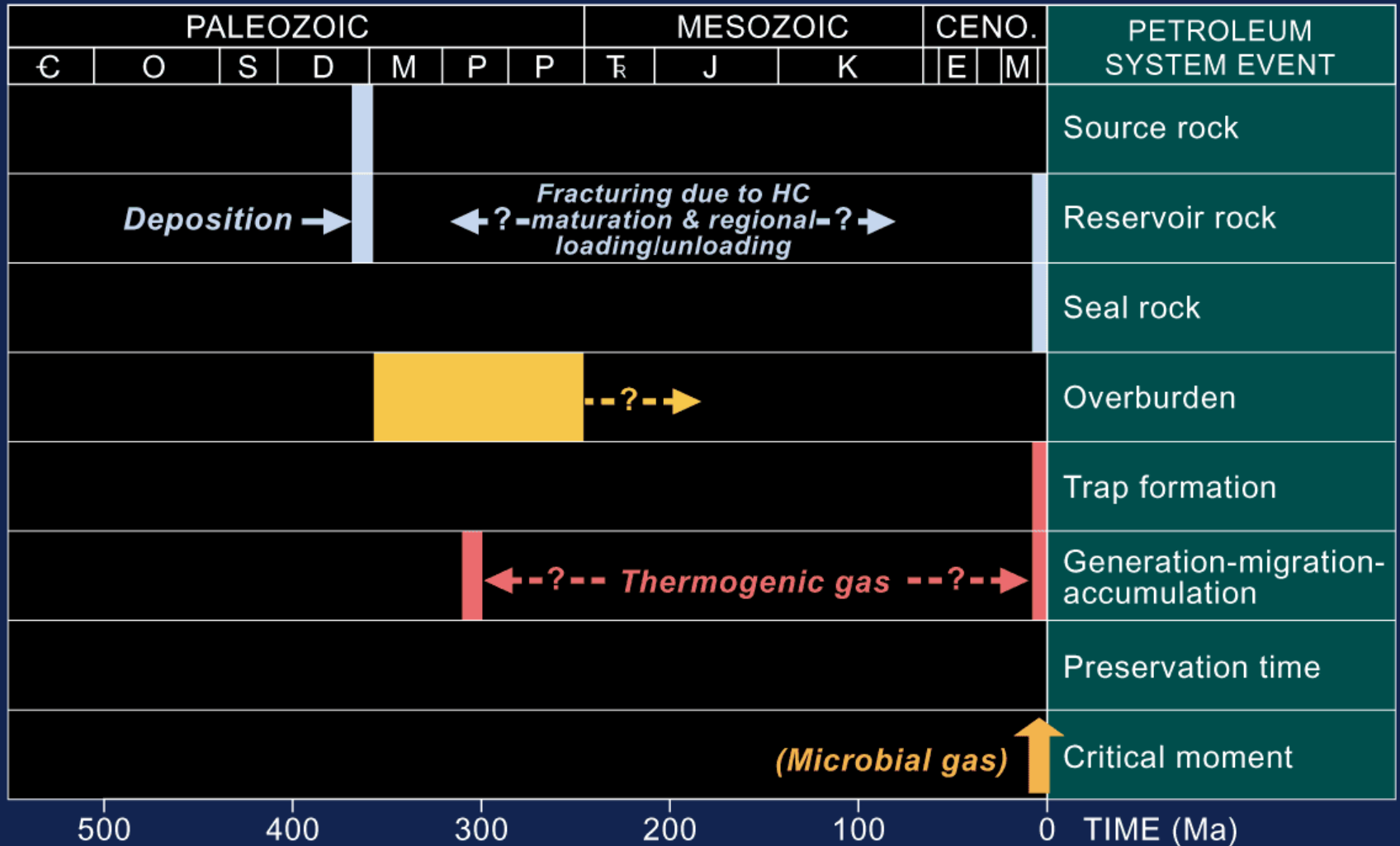


Hydrogeology of New Albany Shale

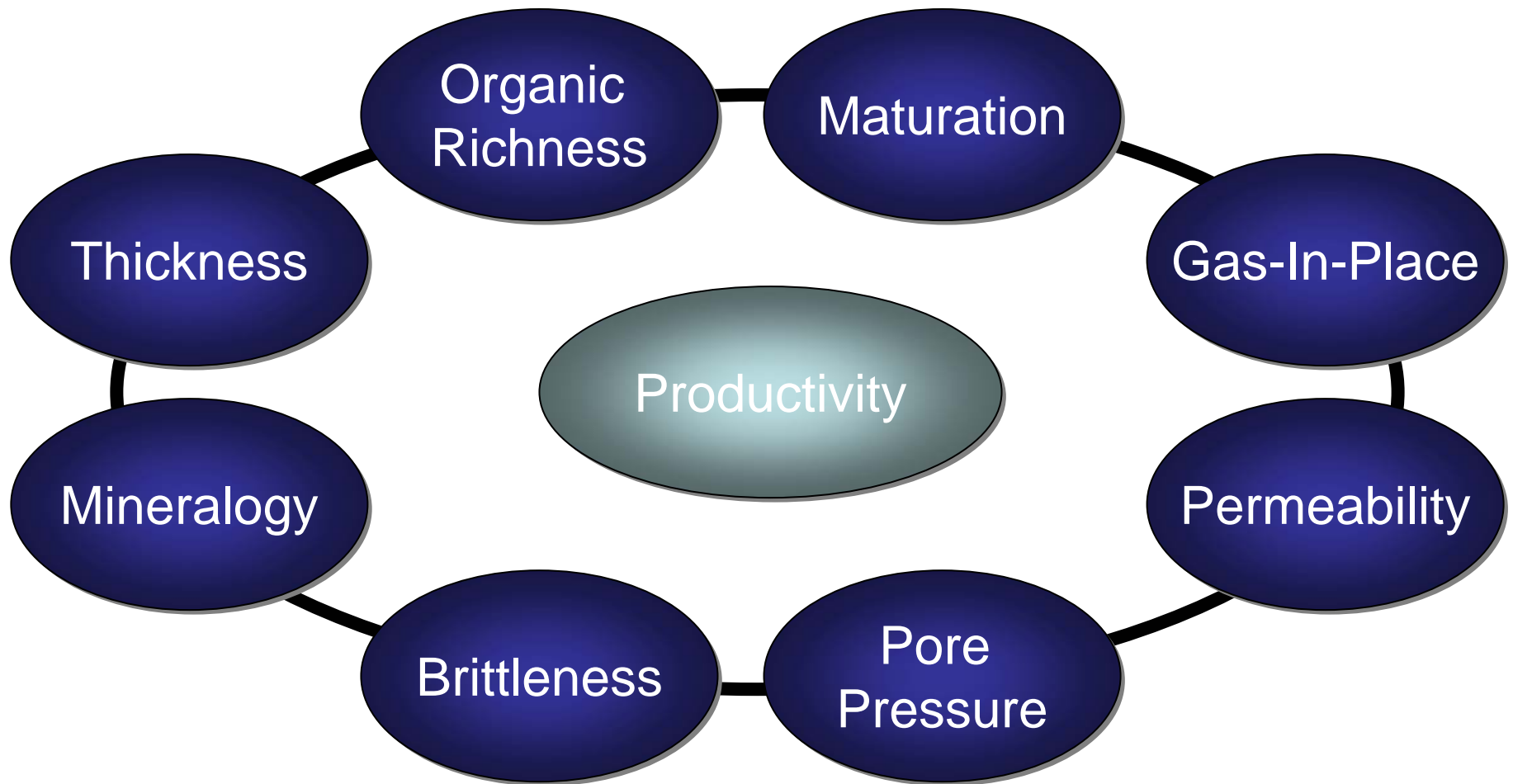
(Walters et al., 2000)



Evolution of Antrim Shale Gas (Curtis, 2002)



Elements of a Successful Shale Gas Play





Potential Gas Agency



Potential Supply of Natural Gas in the United States

***Report of the
Potential Gas Committee
(December 31, 2006)***

Highlights of the 2006 PGC Report

- **Historical gas production trends**
- **Gas shale geology and resource potential**
- **Realities of developing offshore gas resources**
- **Canadian resource assessment and E&P**
- **LNG, methane hydrates and deep gas**
- **Comparison with NPC and EIA assessments**

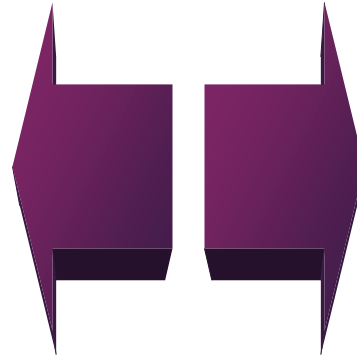


Proved Reserves vs. Resources

- Known gas reservoirs

- Existing economic conditions

- Existing operating conditions



- Discovered

- Undiscovered

- Effects of technology

- Effects of economics



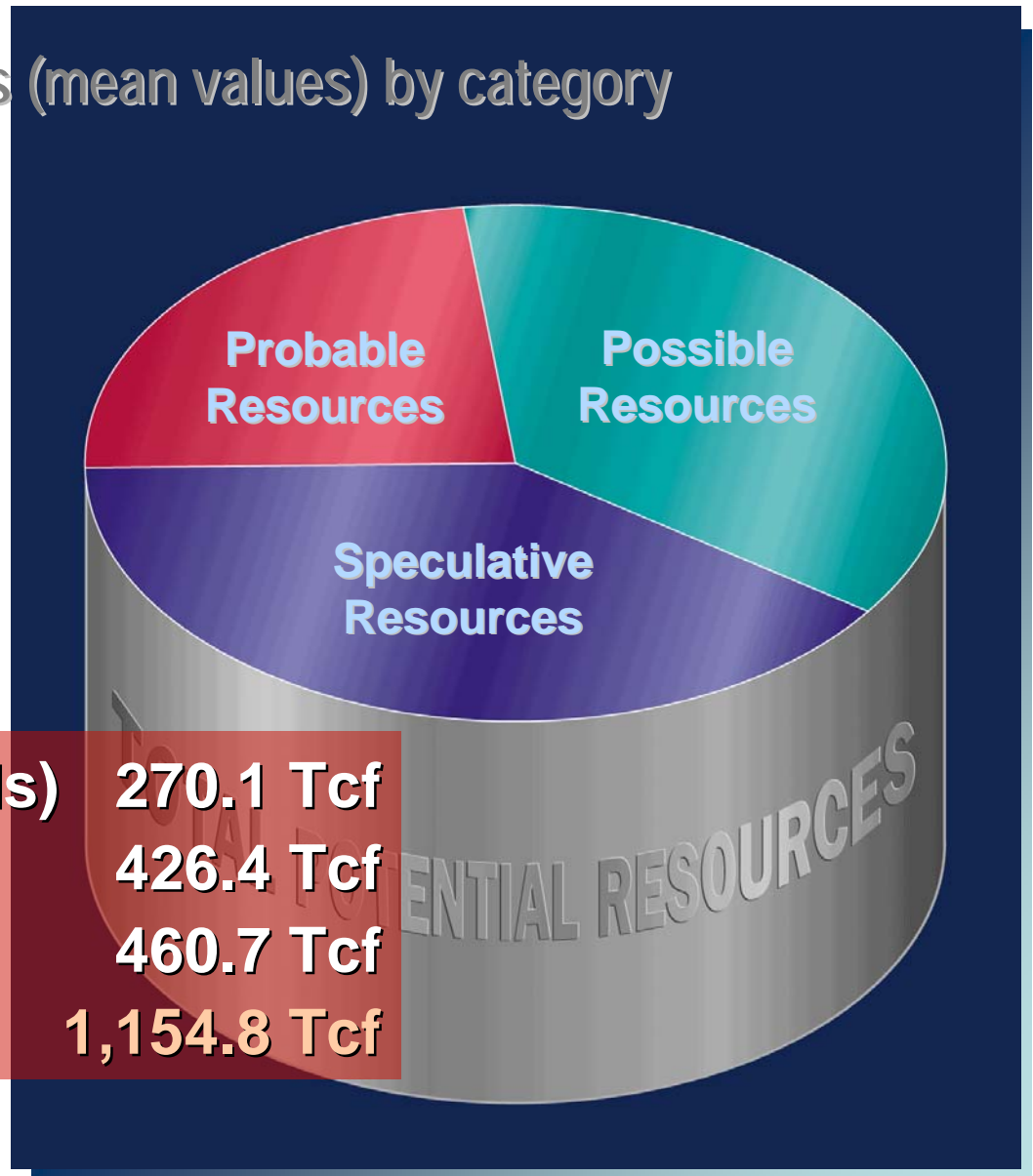
Natural Gas Resource Estimates of the PGC, 2006 (mean values)

Traditional Resources	1,154.8 Tcf
Coalbed Gas Resources	166.1 Tcf
Total U.S. Resources	1,320.9 Tcf
Proved Reserves (EIA)	204.4 Tcf
Future Supply	1,525.3 Tcf



PGC Resource Assessment 2006

Total Traditional Resources (mean values) by category



Probable (existing fields)	270.1 Tcf
Possible (new fields)	426.4 Tcf
Speculative (frontier)	460.7 Tcf
Total	1,154.8 Tcf

PGC Resource Assessment 2006

Total Coalbed Gas Resources (mean values) by category

Probable
Resources

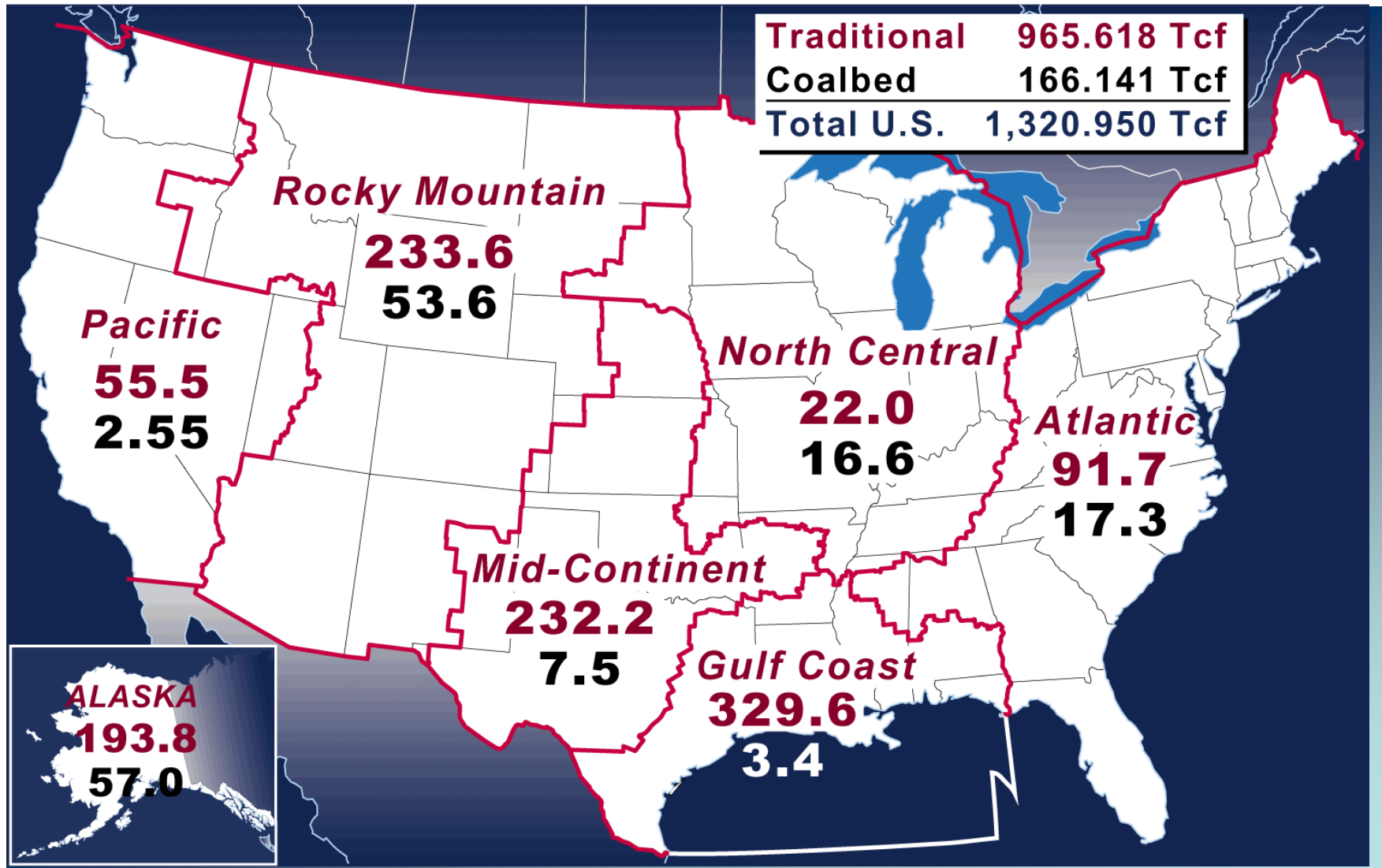
Possible
Resources

Speculative
Resources

Probable (existing fields)	15.5 Tcf
Possible (new fields)	50.9 Tcf
Speculative (frontier)	98.9 Tcf
Total	166.1 Tcf

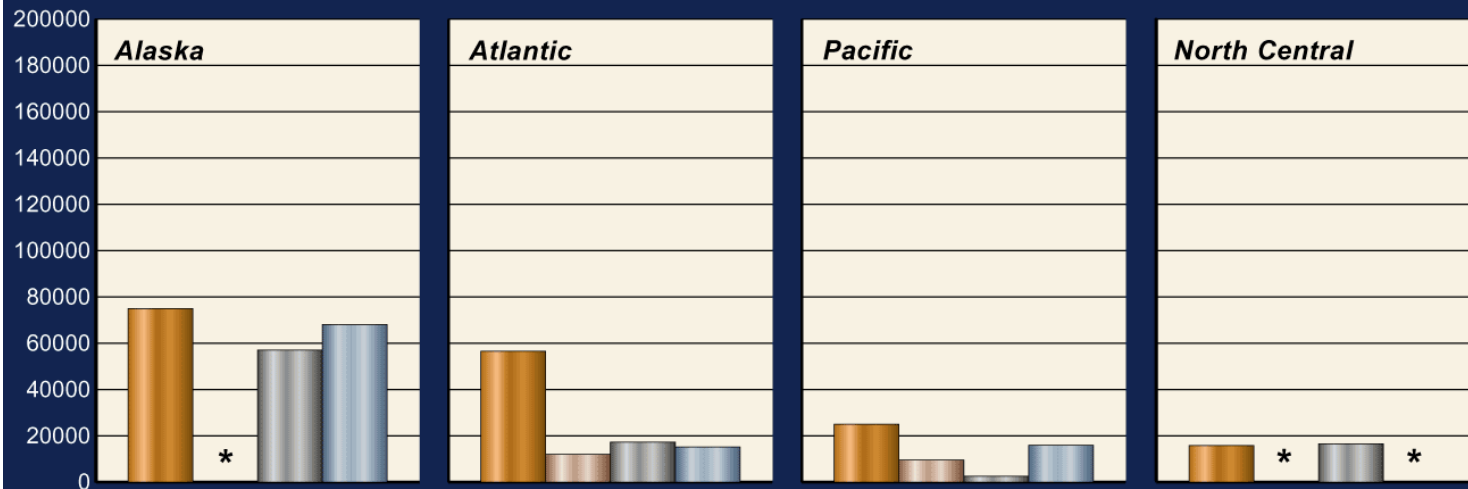
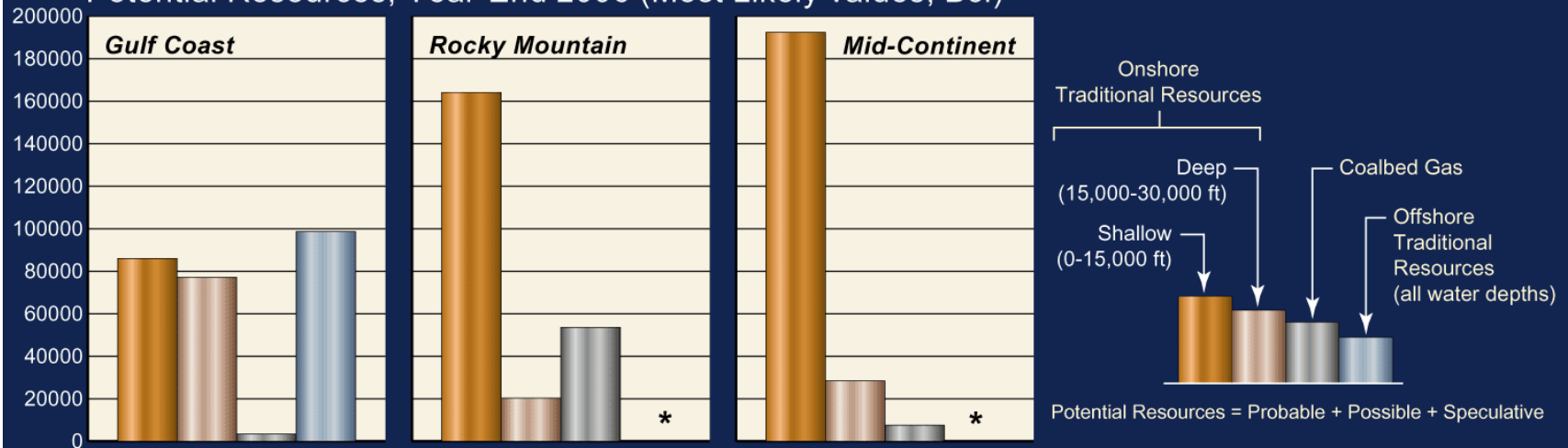
COALBED GAS

Regional Resource Assessment



Regional Resource Comparison

Potential Resources, Year-End 2006 (Most Likely values, Bcf)



* No resources or negligible quantity estimated.

Regional Resource Assessment Summary

PGC Area	Traditional Resources (Mean, Tcf)	Coalbed Gas Resources (M.L., Tcf)	Total Resources (Tcf)	Region's Proportion of Total L48
Gulf Coast	329.6	3.4	332.9	31.2%
Rocky Mountain	233.6	53.6	287.1	26.9%
Mid-Continent	232.2	7.5	239.7	22.5%
Atlantic	91.7	17.3	109.0	10.2%
Pacific	55.5	2.6	58.1	5.5%
North Central	22.1	16.6	38.6	3.6%
Total Lower 48	965.6	100.9	1,065.5	
Alaska	193.8	57.0	250.8	
Total U.S. (means)	1,154.8	166.1	1,320.9	

References

- Curtis, J.B., and S.L. Montgomery, 2002, Recoverable natural gas resource of the United States; summary of recent estimates: AAPG Bulletin, v. 86/10, p. 1671-1678.
- Hill, D.G., and C.R. Nelson, 2000, Gas productive fractured shales; an overview and update: GasTips, v. 6/2, p. 4-13.
- Walter, L.M., J.C. McIntosh, A.M. Martini and J.M. Budai, 2001, Hydrogeochemistry of the New Albany Shale, Illinois Basin; *in* Final Report to Gas Technology Institute, v. 1, phase III, GTI-00/0153, 66 p.